Morphologic and genetic differentiation of natural populations of *Chrysichthys nigrodigitatus* (Siluroidei, Claroteidae)

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Introduction

Chrysichthys nigrodigitatus (Lacépède, 1803) is a silurid found in most of the West African hydrographic basins from Senegal to Zaire. It is an economically important species whose culture in lagoons has been developed in certain countries like Côte d'Ivoire, where the annual production is 350 to 400 t (OTEME, 1993). But as for most fish species of aquacultural interest, the research programs which studied the biological cycle, the production conditions and the commercialization of the species did not take into account the genetic resources of the natural populations. However, the biological characteristics of the populations including their reproduction, depend in part on their genetic patrimony. The knowledge of genetic characteristics of fish species of aquacultural

interest is necessary to characterize the strains and the populations and also to show introgressions (hybridization between close species). It also allows the determination of management schemes (maintenance, study and restoration of the genetic variability of strains, reconstitution of stocks in the natural environment) and improvement plans (comparison of performances of genetically differentiated strains) and finally to create new strains by crossing. The first genetic studies of *C. nigrodigitatus* populations were carried out by AGNESE in 1989 during a study on the genetic differentiation of several West African siluriform species of interest to fisheries and aquaculture. These first works showed that the population from the Niger river (Mali) is very differentiated from those coming from rivers in Côte d'Ivoire. The current work studies the diversity of natural populations of *C. nigrodigitatus* over a larger portion of its distribution range. Two techniques were used to achieve this goal: morphological analysis of samples and enzymatic protein electrophoresis. The main objectives of this study were: to establish reference data which could be used for the management and the protection of natural populations and culture strains, to enable the comparison of zoo-technical performances of the most morphologically and genetically differentiated samples and to propose possible applications for aquaculture.

Materials and methods

Genetic and morphological studies were carried out using eleven samples of *C. nigrodigitatus* from different basins along the West African coast (Fig. 1). The Jacqueville strain is made up of domesticated fish (fifth generation) taken from a fish farm for comparative purposes. Because of preservation problems, certain samples could only be analyzed using one technique.

The morphological analyses were performed by the Ichthyology Laboratory of Tervuren in Belgium. Fifteen metric characteristics and eight meristic characteristics were measured on each specimen.

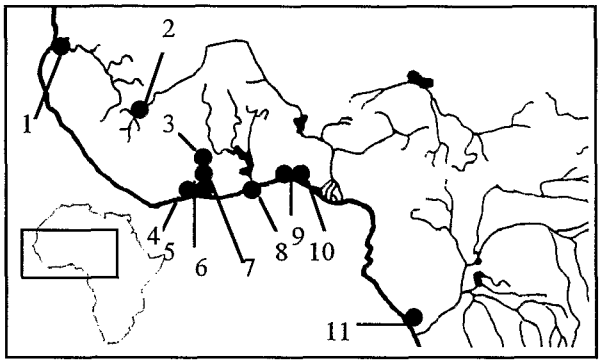

Fig 1
Collecting sites of *Chrysichthys nigrodigitatus* samples: 1, Dagana, 2, Selingue, 3, Abengourou, 4, Layo, 5, Jacqueville, 6 Bonoua, 7, Koutoukro, 8, Bator, 9, Abobo, 10, Guezin, 11, Bas Kouilou.

These were: (1) total length, (2) standard length, (3) head length, (4) snout length, (5) width of the premaxillary band, (6) length of the occipital process, (7) width of the occipital process, (8) length of the nasal barbels, (9) predorsal distance, (10) preadipose distance, (11) prepectoral distance, (12) prepelvic distance, (13) preanal distance, (14) dorsal-adipose distance, (15) dorsal length, number of branchiospines on the epibranchial, number of branchiospines on the cerato- and hypobranchial, number of soft rays in the dorsal fin, number of soft rays in the pectoral fin, number of simple rays in the pelvic fin, number of branched rays in the pelvic fin, number of simple rays in the anal fin, number of branched rays in the anal fin. Statistical analyses of the data were carried out using CSS: Statistica software (Statsoft, version 3.3). The genetic diversity was studied in the Genetics Laboratory at the Centre de Recherches Océanologiques in Abidjan. The electrophoretic analyses studied 19 loci and 8 populations. The genetic variability was evaluated using two indices: i) the polymorphism rate P which corresponds to the number of polymorphous loci compared to the total number of loci studied, ii) the mean heterozygosity (H) calculated using NEI's formula (1978).

Results and discussion

The morphological data obtained for fourteen characteristics, excluding the total length, were subjected to an analysis of principal components; the populations were divided into four groups based on their country of origin (Fig. 2). The nasal barbel length is the most discriminating characteristic on the second axis. The dorsal length, the premaxillary band width and the occipital process length are the most discriminatory on the third axis. The first axis was not taken into account because it was highly influenced by specimen size. Samples from Congo and Côte d'Ivoire were clearly separated from those of Senegal and Mali. There is a great deal of overlapping in the zone occupied by the Congo sample, taken from brackish water near the mouth of the Kouilou, and samples from Côte d'Ivoire. This overlapping is seen particularly with populations from Ebrié Lagoon (Layo, Jaqueville and Bonoua).

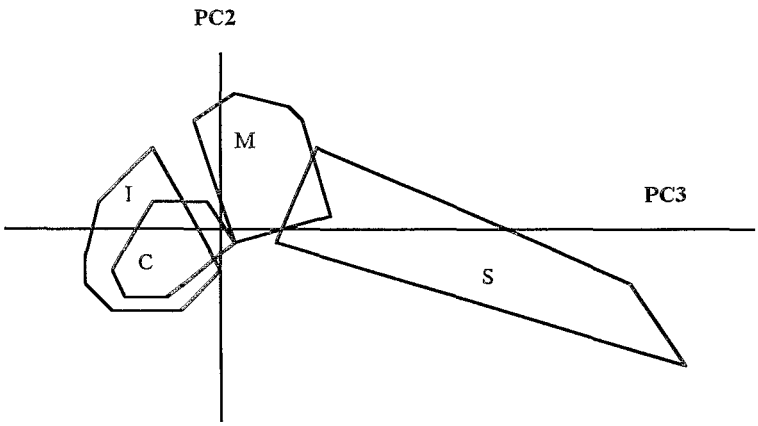

Figure 2
Plot of a principal component analysis using 14 log-tranformed metric variables of *Chrysichthys nigrodigitatus* specimens arranged in groups based on their country of origin: I, Côte d'Ivoire, M, Mali, C, Congo, S, Senegal.

Populations from Mali and Senegal overlap slightly. Concerning meristic characterisitics, only the number of branchiospines on the lower part of the first branchial arch and the number of branched rays in the anal fin showed some variation. The Congo population distinguishes itself from the others by a greater number of branchiospines (15 to 18) and branched rays.

Genetically, of the 19 loci analyzed by enzymatic electrophoresis, 6 were shown to be polymorphic in the *C. nigrodigitatus* samples. The Congo and Senegal samples were monomorphic for all loci studied (Table 1). Those from Layo and Jacqueville showed private alleles EST-1*A and PROT*B. The polymorphism rate, P99, determined for all populations varied from 0.0 (Dagana, Congo) to 15.7 (Layo, Jacqueville) with a mean of 10.5. This rate is comparable to that estimated by AGNESE *et al.* (10.3) in 1989 in the same species and in *C. johnelsi*. The mean heterozygosity rate was 4.1%. This rate was comparable to those found in the literature. AVISE and AQUADRO (1982), estimated it to be 5.4% for all fish in general. Certain African silurids have the following values: 4.7% for *Clarias gariepinus* (VAN DER BANK *et al.*, 1992), 11% in *Heterobranchus longifilis* (TEUGELS *et al.*, 1992).

population	1	2	4	5	8	9	10	11
$P_{99\%}$	0.0	15.7	26.3	21.0	10.5	15.7	15.7	0.0
$H_{\%}$	0.0	5.8	6.3	6.0	4.5	5.3	4.7	0.0

Table 1
Summary of the polymorphism and heterozigosity values observed for the 8 populations of *C. nigrodigitatus* studied.

The highest mean heterozygosity rates were observed from Layo (6.3%) and Jacqueville (6.0%). The Jacqueville population is made up of domestic specimens (fifth generation in captivity) issued from several hundred brooders some of which are taken from the wild each year (Ebrié Lagoon) near Layo. Therefore, the culture technique used avoids loss of genetic variability. In effect, the high

number of brooders used but also the systematic introduction of new wild brooders helps maintain the genetic variability of the original population.

The results obtained using these two techniques show certain similarities. All the *C. nigrodigitatus* populations, with the exception of those from Côte d'Ivoire and Congo, were different morphologically. This differentiation was ordained geographically. In effect, the populations the most differentiated are those which were the most geographically separated (Senegal-Mali and Congo).

Concerning the genetic differentiation, the most polymorphic populations were those from Côte d'Ivoire and the monomorphic populations were located at the limits of the species' distribution (Senegal and Congo).

Conclusion

Knowledge of the genetic diversity of natural populations allows the monitoring of natural stocks the conservation of which may become necessary due to manmade environmental alterations.

From an aquacultural viewpoint, knowledge of the genetic diversity of wild populations allows for appropriate choices in sampling sites and eventual crosses in order to obtain strains with high genetic variability. For example, the Senegal and Congo strains being monomorphic sometimes for different alleles, it would be interesting to perform crosses between them in order to obtain an eventual heterosis effect.

Crosses could be performed between specimens from different populations in order to obtain a synthetic strain possessing the majority of the variability of the species. So that a cross between individuals from Côte d'Ivoire and Niger would produce a strain possessing most of the alleles of the species. Such a synthetic strain would be likely to have zoo-technical advantages (growth rates,

resistance to disease as well as to other environmental aggressions, etc...) because of its high genetic variability. In effect, different studies (DAZMANN *et al.*, 1986, 1987, 1988, 1989; MITTON and GRANT, 1984; ALLENDORF and LEARY, 1986; ZOUROS and FOLTZ, 1987; 1990; AGNESE *et al.*, 1994) of the relationships between the genetic variability and zoo-technical aptitudes have shown the existence of a correlation between these two types of factors. These works have shown that heterozygous specimens often have zoo-technical performances (growth, viability and fecundity rates; egg size; disease and environmental stress resistance, etc...) much higher than homozygous specimens. This strain may also be capable of a greater adaptive ability to captive conditions.

Knowledge of the genetic variability of cultured strains would allow the monitoring of these stock in time and space and notably to confirm the absence of introgression. As an example, this study shows that the domestic strain (Jacqueville) shows a polymorphism rate as high as that of the natural population it originates from. Therefore, there has been no loss of variability, contrary to what has been shown for *Heterobranchus longifilis* (AGNESE *et al.*, 1994). In effect, in the domestic strain of this species, a loss of genetic variability, in comparison to the natural population, has been observed in fourth-generation captive specimens. This loss is accompanied by a strong decrease in larval survival rates. On the contrary, in *C. nigrodigitatus*, no new alleles have been observed among domestic strains, which indicates the absence of introgression in these stocks.

Finally, it would be interesting to test the zoo-technical performances of specimens from the most polymorphic populations (Côte d'Ivoire, Ghana, Togo, Benin).

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